expressed in this order: 1, Delicious; 2, Rome Beauty; 3 Jonathan; 4, Winesap; 5, Newtown.

When the dew point ranges between 30° and 31°, a minimum temperature of 27.8° with a duration below 32° of 5^h 30^m and at 28° of 1^h 10^m produces damage to all varieties except Newtown. This damage is of two kinds—(1) where the seeds are killed, and (2) where the skin is frostmarked but the seeds are not killed. Either type of damage, however, is commercial damage. The relative susceptibility to damage of the different varieties under this condition as expressed on a scale of the number of fruits damaged is: Delicious, 89%; Rome Beauty, 85%; Winesap, 70%; Jonathan, 50%; and Newtown, 0%.

CONCLUSIONS

While the observations on which this study is based cover a period of four spring seasons only, the mass of evidence is sufficiently great to enable these generalizations to be made:

1. The temperature of the dew point at the time of the frost, which can be correlated with the temperature of the dew point at 4.40 p. m. on the afternoon preceding the frost, is too important a factor to be neglected; any accurate scale of critical temperatures for apples must take it into consideration. The data are mere chaos if the dew-point factor be neglected; when it is considered, the evidence fits nicely into an ordered system. Herein, we believe, lies the reason for the dissatisfaction of the growers with the old scales of critical temperatures, for these scales took no account of the amount of water vapor in the air.

Evidence in this paper shows unmistakably that the dew point at the time of the frost has a very important bearing on the amount of damage that will be caused by low temperature. When the dew point is 32° when the air temperature reaches 32°, and the dew point falls as the temperature falls, severely low minimum temperatures can be endured with but slight damage, whereas the same temperature conditions with a low dew point will cause very severe damage. Comparison of the frost on April 4, 1926, in test plot No. 11 with the frost on April 15, 1924, in test plot No. 7, brings out this point in a forceful manner. On April 4, 1926, occurred a minimum temperature of 22.9°. The temperature remained 9^h 50^m below 32° with a duration of 1^h 10^m at 23° with an evening dew point of 37°. On April 15, 1924, occurred a minimum temperature of 26.8°. The temperature remained 3^h 55^m below 32° with a duration of only 0^h 20^m at 27° with an evening dew point of 23°. In each case there was observed relatively the same amounts of damage to Winesap in stage 6.

It is highly probable that one of the reasons such great damage occurs with low dew-point temperature is to be found in the simple relation that exists between the temperature of the dew point and the rate at which the air temperature rises following a frost. As a general rule, the lower the dew-point temperature, the faster is the rate of rise in air temperature after sunrise.

2. Many conditions define the point at which damage begins with apples in the different stages of development. These conditions are made up of several different factors, chief among which are (1) the temperature of the dew point, and (2) the duration of temperature at different temperature levels below 32°. Other factors, too, bear on the amount of damage that will be caused by any damaging temperature conditions, chief among which are (1) the rate of rise in temperature after sunrise, and (2) the vitality of the individual tree. The scale of critical temperatures, therefore, necessarily must be complex, and judgment will be required for its practical application.

3. Different varieties of apples show different degrees of resistance to frost. Furthermore, each variety seems to have a particular stage or stages of development wherein it is particularly susceptible to injury. Thus, for instance, Delicious and Winesap show relatively the same measure of resistance to a given condition in the earlier stages of development, but in later stages Delicious proves to be more tender than Winesap.

ACKNOWLEDGMENT

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F. M. EXNER ON DYNAMICAL METEOROLOGY

By EDGAR W. WOOLARD

The state of the atmosphere in respect to what is commonly thought of as weather is completely specified by the six meteorological elements (temperature, pressure, humidity, wind, cloud, and precipitation), which in turn are fully determined by seven physical quantities, viz, temperature, pressure, density, the three components of wind velocity, and the joint mass of solid, liquid, and gaseous water per unit mass of atmosphere. All these seven are dynamical or thermodynamical variables; and hence meteorology, regarded (in accordance with modern tendency) as restricted to the investigation of weather phenomena purely, may be defined as the dynamics and thermodynamics of the earth's atmosphere. And it is with the investigation of weather considered as a dynamical and thermodynamical process that the volume here to be reviewed is concerned.

Weather phenomena are in general so complex and irregular that even a purely empirical understanding of them was very slow to develop; and, although we can not doubt that they are only manifestations of ordinary physical laws, the intricate manner in which a great multitude of influences simultaneously operate to bring about the final result makes it a task of extreme difficulty to bring the facts of daily weather into direct relation with physical principles. Consequently we still are forced to rely extensively upon empirical and statistical methods; but such methods are of limited power, and it is imperative that every possible effort be made to advance further the exact mathematical and physical theory of atmospheric processes, and to adapt this knowledge to practical needs. In spite of the difficulties, steady and encouraging progress in this direction is constantly being effected.

The advancement and the utilization of any subject are much facilitated if there be readily available to students and investigators a comprehensive treatise that summarizes existing knowledge and directs the reader to the literature. In the case of meteorolgy, this need is largely met by Felix M. Exner's *Dynamische Meteorologie,* which first appeared in 1917, and of which a second and enlarged edition has recently been published (Julius Springer, Wien, 1925). The author is well fitted for his task, and his own original contributions fill many of the pages. The book forms a most excellent summary of our present knowledge of theoretical meteorology, and is indispensable to every student of this important aspect of the science of the weather.

The earth's atmosphere is a particular example of the gaseous envelopes that surround most celestial bodies, the general dynamical theory of which has been worked out by Laplace, Stoney, Milne, and others. The production and the maintenance of the physical activity in this atmosphere that constitutes weather requires energy, of which the ultimate source (except for an infinitesimal fraction) is incident solar radiation; the study of the amount, distribution, disposal, and effects of the latter is fundamental to meteorology, but forms an extensive and separate subject in itself. Under the stimulus of solar energy, atmospheric phenomena take place in accordance with the general laws of dynamics and of thermodynamics that rule all physical systems, but these phenomena are conditioned by the special circumstances peculiar to the terrestrial atmosphere—the composition and general chemical and physical properties of atmospheric air, the nature of the energy supply, the particular forces operating, etc. The atmosphere acts like a great thermodynamic engine, transforming solar energy into the energy of atmospheric processes; and the general problem of meteorology is to give a complete and continuous account of the resulting phenomena and their mechanism.

After a brief introduction, and an account of the gravity field of the earth, Exner opens the subject by establishing the fundamental general physical laws to which all weather phenomena, whatever they may turn out to be, must conform. The first chapter takes up the thermodynamical relations that hold in the atmosphere—the gas laws for dry and for moist air, the equations applying to the dry, rain, hail, and snow stages, etc. The graphical methods recently introduced by Shaw are not mentioned. Although the specific heat of water vapor is quite uncertain, the value given on page 14 does not seem to be admissible. In the second chapter, the general dynamical equations are derived; this is a topic that must be developed with great care if confusion and obscurity are to be prevented in the mind of the student, and the reviewer does not consider that Exner's presentation is particularly good. Incidentally, the use of left-handed axes on page 20 and elsewhere in the book is regrettable. The last equation on page 20 should be divided through by cos ϕ to make the statement at the top of page 21 strictly true; and the assertion in the last paragraph of Article 13 is, to say the least, misleading.

In the next six chapters, the general principles and laws of particular atmospheric processes are developed. The treatment of static equilibrium occupies the third and fourth chapters, and includes a discussion of the necessary and sufficient conditions for equilibrium, the stability of the atmosphere, the hypsometric equation, the effects of convection on the temperature of and within rising air, the three types of ideal equilibrium (conductive, convective, and radiative), and the causes of the observed distribution of temperature in the vertical. The difficulties recently brought to light in the theory of thermal convection (*cf.*, e. g., *Met. Mag.*, 60, 253, 1925) are not discussed. The fifth and sixth chapters take up the general theory of winds, including kinematics (stream lines, the equation of continuity, etc., with applications to such phenomena as the foehn and orographic precipitation), the dynamical theory of horizontal motion with and without friction, atmospheric turbulence and its effects, vertical motions, and the Bjerknes circulation theorem. Much important work on turbulence has been done since the publication of the book. In view of the possibility of investigating certain meteorological phenomena by means of model experiments, the section on dynamical similarity is of great interest. In connection with the discussion on page 125, it should be pointed out that air masses have no mean free path, and that Taylor has provided a theory of diffusion by continous movements—diffusion by turbulence is not exactly analogous to diffusion by molecular motions, and while the latter may be suggestive in this connection, an independent theory for the former is necessary. The extremely important subject of dynamic equilibrium is treated in the eighth chapter, in which are developed the conditions necessary to steady motion both in the case of continuous gradients and in the case of the presence of discontinuities. At a number of different places in the book, it is pointed out that the atmosphere as a whole is probably not far from a steady state of dynamic equilibrium; and that storms and other phenomena probably originate by reason of disturbances of such a steady state rather than from disturbances of a state of static equilibrium.

The thermodynamics of equilibrium and motion in the earth's atmosphere occupies the seventh chapter. An extensive account is given of the important contributions of Margules; while thermal cycles, the formation of vortices, the dissipation of energy through turbulence, etc., also receive attention. Certain theorems of Sandström, concerning equilibrium, have since been shown by Jeffreys to be incorrect, however.

The preceding material occupies about half the book; and forms the basis upon which an attempt is made in the remaining chapters to construct a rational theory of observed weather sequences. Fundamental in any such attempt, of course, is a theory of atmospheric circulation; and the ninth chapter is devoted to a review of the none too complete facts of observation concerning the distribution of winds and other meteorological quantities throughout the atmosphere of the globe, together with an attempt at a qualitative explanation. Of great interest is the suggestion, on page 217, as to how the interlatitudinal circulation must necessarily take place by way of cyclones and anticyclones, the dynamical foundation for which has since been supplied by Jeffreys. Ångström has pointed out a numerical error in the discussion, on page 239, of the relation between atmospheric circulation and the distribution of energy income over the surface of the globe, as a result of which Exner's value of the *austausch* is 60 times too large. The purely kinematical and dynamical aspects of the secondary circulations are considered in the tenth chapter, and the question of the extent to which revolving fluid can be made to account for the observed phenomena is examined.

An interesting, and as yet incompletely solved, problem is presented by the mechanism of the conversion of radiant energy into the kinetic energy of the various atmospheric circulations. Undoubtedly, the primary cause of the general circulation is the unequal heating and cooling at different latitudes, operating through the temperature (and hence pressure) differences thereby engendered; while cyclones and anticyclones seem to be a necessary condition for the resulting interlatitudinal exchange of air, for this exchange, modified and complicated by numerous influences, does not take place in any regular and constant manner and is broken up into a series of secondary circulations. The energy of atmospheric circulations thus comes originally from the unequal heating at different latitudes, i. e., from major convection currents, but the processes, especially in the case of the secondary circulations, are not so simple and clear as imagined in the older theories. There is rather general agreement, however, that but little solar energy is transformed directly into kinetic energy—rather it is mostly stored up in some form of potential energy that subsequently, when conditions become right, is released in the kinetic form. Of the various conceivable immediate sources of the kinetic energy of storms, Margules found we must look to the inherent gravitational potential energy of position between adjacent masses of air of different potential temperatures for the main supply, although under favorable circumstances latent heat of condensation is also an important source. In a state of dynamic equilibrium, warm and cold air may lie side by side without any disturbance arising—the potential energy capable of giving rise to a storm is present, but is not released until the conditions essential to the equilibrium are interfered with. This conception plays an important part in some modern theories of the cyclone.

Finally, in the eleventh and twelfth chapters, Exner reaches what is really the ultimate objective of theoretical meteorology—the problem of the actual sequence of day-to-day weather. In these chapters we find a wealth of valuable and interesting material which we can not here even mention in detail. The extensive accounts of the "tropfentheorie" or "barrier theory" of cyclone genesis and of the high "upper cyclones" of the Austrian school should be particularly interesting to American meteorologists, who are not in general very familiar with these ideas. Some striking instances of the value of aerological data to the interpretation of the phenomena on surface synoptic charts are given on pages 379–382.

In the final chapter are given the dynamical theories of gravitational waves at the interface between two strata of differing density; the diurnal variations of wind, pressure, and temperature; and the free vibrations of the atmosphere. Throughout the book, numerous references to the original literature are given; and a good index completes the volume.

THE "JANUARY THAW"

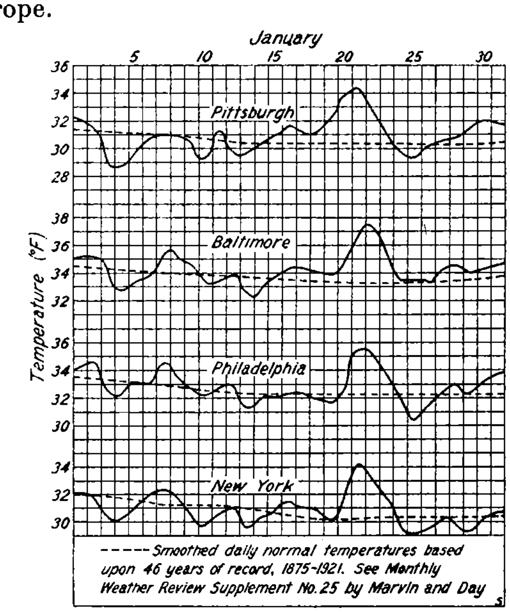
By ROSCOE NUNN

[Weather Bureau Office, Baltimore, Md.]

The popular belief in a "January thaw"—the more or less regular occurrence of a mild spell in the latter part of January—seems to find support in the temperature records of Baltimore and other stations in the Eastern States, from Georgia to New England. An examination of the Weather Bureau records of daily mean temperatures for the last 50 or 54 years discloses a marked crest in the graphs of the average daily mean temperatures for the three-day period, January 21–23, at Baltimore, Philadelphia, New York, Boston, Pittsburgh, Raleigh, and Atlanta. The crest is apparently most pronounced over the Middle and North Atlantic States. The accompanying graphs for Pittsburgh, Baltimore, Philadelphia, and New York show the prominence of the crest.

It is not the purpose of the writer to attempt to show that the "January thaw" is an established periodicity. Reliable and fairly homogeneous records for a half century show that it has occurred often enough to leave a marked impress upon the records for that period. Whether the succeeding 50 years shall tend to obliterate this crest, maintain it, or increase it, remains to be seen. The feature is a striking and interesting one in the Baltimore station records, although it may be of little value as an indication of future happenings.

"January thaw" was a saying many years before records of satisfactory authenticity had been established. It is mentioned by Greely in his "American Weather," published in 1888. It is mentioned by W. M. Esten and C. J. Mason in a discussion of weather records for Storrs, Conn., published in September, 1910. However, but little has been published upon the subject, as shown by Talman in his compilation of references to literature concerning supposed irregularities in the annual march of temperature, in the MONTHLY WEATHER REVIEW for August, 1919. Talman shows that the "January thaw" is popularly looked for in America, especially in New England. Apparently, the thaw has not been recognized in Europe.



The most comprehensive discussion of the general question of annual recurrences is found in a paper by Prof. C. F. Marvin, in the MONTHLY WEATHER REVIEW for August, 1919. Subsequently to this, in March, 1925, Professor Marvin wrote further on the subject, in a